Subterranean Biology 52: 29–44 (2025)
doi: 10.3897/subtbiol.52.140693
https://subtbiol.pensoft.net

DATA PAPER

A peer-reviewed open-access journal
Subterranean Biology
Published by The International Society for Subterranean Biology

Integrating formal surveys and local knowledge: Insights into the subterranean fauna of Apulia

Sarah Boulamail[1], Salvatore Inguscio[2,3], Sara Ventruti[4], Benedetta Barzaghi[5,6], Damiano Brognoli[5], Raffaele De Giorgi[4], Joachim Langeneck[7], Elia Lo Parrino[5], Emanuele Mancini[4,9], Raoul Manenti[5,6], Alejandro Martínez[8], Martina Pulieri[4], Emanuela Rossi[2,3], Francesco Cozzoli[1,4,9]

1 *Research Institute on Terrestrial Ecosystems (IRET) - National Research Council of Italy (CNR) URT Lecce, Palazzina A - Complesso Ecotekne, via Monteroni 165 73100 Lecce (LE), Italy* **2** *Laboratorio Ipogeo salentino di Biospeleologia "Sandro Ruffo", via Michele Grasso1 73048 Nardò(LE), Nardò, Italy* **3** *Gruppo Speleologico Tricase, via S. Lucia 9 73030 Tiggiano, 73100 Lecce, Italy* **4** *Department of Biological and Environmental Sciences and Technologies, Palazzina B - Complesso Ecotekne, via Monteroni 165 73100 Lecce (LE), Italy* **5** *Department of Environmental Sciences and Policy, Università degli Studi di Milano, Via celoria, 10, 20133 Milano, Italy* **6** *Laboratory of Subterranean Biology "E. Pezzoli", Parco Regionale del Monte Barro, Località Eremo, 1, 23851 Galbiate (LC), Italy* **7** *Consorzio Nazionale Interuniversitario per le Scienze del Mare (CoNISMa), U.L.R. di Lecce, c/o Department of Biological and Environmental Sciences and Technologies, Palazzina A - Complesso Ecotekne, via Monteroni 165, 73100 Lecce (LE), Italy* **8** *Molecular Ecology Group, Water Research Institute, National Research Council of Italy, Largo Tonolli, 50. 28922. Pallanza, Italy* **9** *National Biodiversity Future Center (NBFC), Palermo, Italy*

Corresponding author: Francesco Cozzoli (francesco.cozzoli@cnr.it)

Academic editor: Tiziana Di Lorenzo | Received 5 November 2024 | Accepted 4 February 2025 | Published 21 May 2025

https://zoobank.org/5CD993C0-5B95-4194-8954-5F68B6DC8F9F

Citation: Boulamail S, Inguscio S, Ventruti S, Barzaghi B, Brognoli D, De Giorgi R, Langeneck J, Lo Parrino E, Mancini E, Manenti R, Martínez A, Pulieri M, Rossi E, Cozzoli F (2025) Integrating formal surveys and local knowledge: Insights into the subterranean fauna of Apulia. Subterranean Biology 52: 29–44. https://doi.org/10.3897/subtbiol.52.140693

Abstract
The study of hypogean fauna is critical for preserving subterranean biodiversity and ecosystem functions despite climate change. However, underground habitats, often hosting unique and endemic species, present significant challenges for traditional biodiversity assessments owing to their inaccessibility and the specialised nature of their inhabitants, resulting in a paucity of academic studies. Furthermore, even when these studies exist, data are often held in personal notes and databases that are not interoperable according to current standards, making them less usable for research purposes. Reawakening this dormant data,

standardising, and sharing it according to modern criteria offers enormous opportunities to expand existing knowledge and provide support for future studies.

In the Apulian region of Southern Italy, a biodiversity hotspot for subterranean life, the paucity of recent systematic surveys and reliance on expert knowledge poses both opportunities and challenges for ecological research. By integrating data from various sources, this study provides an overview of the subterranean faunal assemblages documented in this region. Overall, the dataset is comprehensive, comprising 109 species (29 of which are considered endemic to Apulia) and 224 sites, totalling 622 presence-only records. As our records have expanded over 93 years, this dataset represents a unique resource for elucidating the characteristics of Apulian subterranean ecosystems and potentially their changes over time. Integrating observations already published in previous studies with unpublished records, this is the first complete data collection on Apulian subterranean fauna organised according to modern standards of data sharing.

Keywords
Apulia, biodiversity hotspot, historical data, presence-only, subterranean fauna

Introduction

Groundwater ecosystems remain understudied due to the inherent challenges posed by subterranean habitats. The inaccessibility of these environments, combined with the specialised and often cryptic nature of their inhabitants, makes traditional biodiversity assessment methods difficult to implement and, in many cases, insufficient (Mammola et al. 2020). Even when studies on hypogean fauna are conducted, the resulting data are frequently stored in personal notes, project-specific datasets, or non-standardised formats that are not interoperable with modern data management practices. Such limitations hinder the ability to build a comprehensive understanding of subterranean biodiversity, its drivers, and its vulnerabilities (Neimanis 2023). By applying modern data management frameworks, these fragmented datasets can be transformed into cohesive resources, enabling the integration of existing knowledge with new findings. Moreover, standardised and shared data can inform conservation strategies, guide sustainable groundwater management, and support compliance with international biodiversity directives (Di Lorenzo et al. 2024).

Study site

Apulia is one of the most interesting and fascinating European karst areas in terms of subterranean biodiversity (Pesce et al. 1978). A long and notable tradition of speleobiological research exists in this region, encompassing pioneering studies of Caroli (1937) and Stammer (1937) in the 1920s and the 1930s, the significant contributions of S. Ruffo in the 1940s (for example Ruffo 1948; Ruffo 1949; Ruffo 1955) and the extensive investigations by G. L. Pesce from the 1970s to 2000 (e.g. Pesce 1983; Pesce 1985). However, our understanding of the Apulian underground fauna remains incomplete. Observations have often been limited in scope, scattered across various

time periods, and lacking systematic continuity, leaving critical gaps in our knowledge of the region's subterranean biodiversity. This discontinuity hinders efforts to build a comprehensive understanding of species distribution, ecological interactions, and potential responses to environmental changes. To help bridge this knowledge gap, this study compiles, reviews, and organises the available information on Apulian subterranean biodiversity in accordance with current standards for data management, availability, and sharing (see Wilkinson et al. 2016).

Geology and hydrogeology

The karst landscape of Apulia, covering approximately 8,600 km^2, includes over 2,300 natural caves, several of which are show caves or touristic sites, and holds historical significance with rock settlements, various hypogea, and numerous important Palaeolithic and Neolithic sites. The Alta Murgia Regional Park, which includes a large part of the corresponding aquifer, was designated as the 12th Italian UNESCO Geopark on 9 September 2024. However, as one of the southernmost major aquifers in Europe, southern Apulia's groundwater temperatures are relatively high and potentially subjected to the effects of global warming (Casarano et al. 2019). Moreover, due to the extensive connection with marine waters, increasing aridity, impacting land use (agricultural, industrial), and consistent and often uncontrolled human groundwater extraction, Apulian groundwaters are particularly exposed to chemical stress, including salinisation (ISPRA 2014).

Apulia is divided into six main hydrogeological units: Gargano, Tavoliere, Murge Plateau, Brindisi Plain, Ionian Arch of Taranto, and Salento (Bitetto et al. 2008, Fig. 1). The groundwater in the extreme northwestern part of the region (Daunia) is continuous with the Central-Southern Apennine aquifer. The Tavoliere consists of a shallow, porous aquifer less than a few dozen meters deep, with a clayey impermeable bottom (Cotecchia and Polemio 1998). The Brindisi Plain is a structural depression of the Mesozoic carbonate basement filled by sediments from the Fossa Bradanica and terraced marine deposits. The Ionian Arch of Taranto, corresponding to the area where the limestone hills of the Murge slope steeply towards the sea, whose deep aquifer is fed by the Murge Plateau, is characterised by numerous important coastal and submarine springs. The remaining three units, Gargano, Murge, and Salento, are characterised by a high proportion of soluble Cretaceous limestone. The action of weakly acidic waters on carbonate rocks in these latter units has led to the development of extensive karst phenomena, resulting in a variety of surface and subsurface karst landforms, whereas surface water is limited because it rapidly infiltrates through fractures or sinkholes into the subsoil, leading to most freshwater movement occurring underground (Parise et al. 2015). Aquifers in the Gargano and Murge regions are under artesian pressure, except along narrow coastal strips, while in Salento, water flows predominantly under phreatic conditions (Cotecchia and Polemio 1998). The Salento hydrogeological unit is unique in that it is bordered by the sea on both sides.

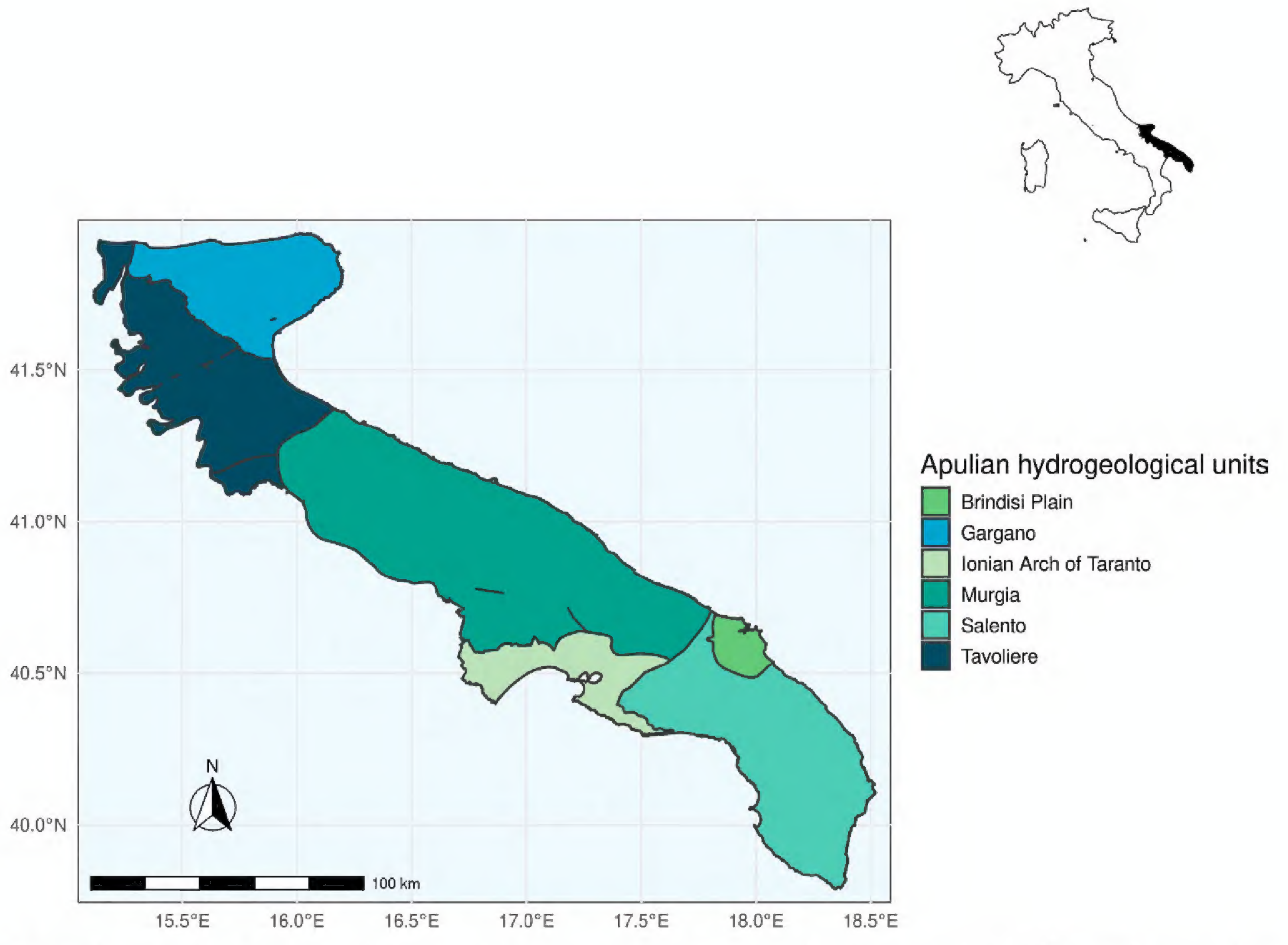

Figure 1. Apulian hydrogeological units (from project Tiziano, Bitetto et al. 2008). The different units are reported in colour.

Apulian stygofauna

The entire Apulia region, especially Salento, has undergone multiple marine regressions and transgressions throughout its geological history (Milia et al. 2017). These events have shaped the evolution of its rich and highly diverse stygofauna, which include numerous ancient, specialised, and rare stygobionts (Rossi and Inguscio 2001). Many of these stygobionts are endemic to Apulia and represent some of the oldest and most significant components of Italian stygofauna (Pesce 1985; Rossi and Inguscio 2001). Apulia shares only a few, relatively recently adapted stygobionts or eustygophiles with the neighbouring Apennine province, including species such as *Diacyclops cosanus* Stella & Salvadori, 1954, *Thermocyclops oblongatus* (Sars G.O., 1927), and *Niphargus longicaudatus* Costa, 1851. The stygobionts of Apulia have various origins and ages. The species with the oldest origins, such as those belonging to the genera *Metahadzia* Stock, 1977, *Monodella* Ruffo, 1949, *Spelaeomysis* Caroli, 1924, *Stygiomysis* Caroli, 1937, and *Typhlocaris* Calman, 1909, are palaeomediterranean elements that colonised the region during the Tethys period (Pesce 1985). In contrast, the presence of other species that originated more recently and that display broader euryhalinity reflects more recent colonisation of Apulian groundwater environments (Ariani 1982; Pesce 1985).

Apulian troglobionts

Although still noteworthy, the subterranean terrestrial fauna in Apulia is less diverse than the aquatic fauna. This significant disparity is likely due to the numerous marine transgressions that modified the distribution of terrestrial species (Inguscio et al. 2010). Among the most prominent endemic troglobitic species are the scaritine carabid *Italodytes stammeri* (Müller, 1938), pseudoscorpion *Hadoblothrus gigas* (Caporiacco, 1951), and collembolan *Troglopedetes ruffoi* Delamare-Deboutteville, 1951.

Methods

The bibliographic dataset was compiled based on the authors' personal knowledge of the limited literature existing on Apulian stygofauna, supplemented by: a) a systematic bibliographic search conducted using Google Scholar, SCOPUS, and ISI Web with the keywords "Apulia" ∧ ("Stygofauna" | "Groundwater fauna") in both English and Italian; b) a substantial collection of unpublished records primarily contributed by Salvatore Inguscio and other amateur biospeleologists; c) the consultation of updated sources such as The New Checklist of Italian Fauna (Bologna et al. 2023). Owing to the incomplete and fragmentary nature of the available knowledge, our dataset does not claim to comprehensively cover the entire body of information on Apulian subterranean fauna, particularly regarding insects. However, the dataset will undergo continuous updates as part of the STIGE-CLIMAQUIFERI project. These updates incorporate both new observations and previously documented information that is currently not included.

Observations reported in the literature were collected using various methods, primarily visual surveys, baited traps, and plankton nets. Novel or repeated observations dated between 2020 and 2024 were collected mainly from the authors of this study using two different sampling techniques. The first method involved the use of a hand-operated net with a mesh size of 0.5 mm; three replicates of 10 shots each were taken at each sampling point. The second method consisted of the deployment of plastic cylindrical traps (length 30 cm and diameter 6 cm) baited with fish or meat fragments. The collected material was fixed in 85% ethanol and preserved in 75% ethanol. In the laboratory, the collected material was sorted, and the specimens were identified at the species level using a stereomicroscope (Olympus SZX-16) and an optical microscope (Leica DM2000LED).

Specimens have been identified morphologically mostly to the species level, with occasional classifications at the genus or subspecies level, and categorised based on taxonomy, lifestyle (aquatic or terrestrial), degree of adaptation to subterranean environments (stygo- and troglobites, stygo- and trogloxenes, and stygo- and troglophiles), and endemic status of the species within Apulian aquifers (TRUE or FALSE). These classifications were primarily based on Ruffo (1955), Pesce (1983), and Karaman (1993), supplemented by a review of more recent sources such as The New Checklist of Italian Fauna (Bologna et al. 2023). The sites are categorised into five typologies (Caves, Wells, Sinkholes, Springs, and Draining Galleries) and six hydrogeological

units: Tavoliere, Gargano, Murge Plateau, Brindisi Plain, Ionian Arch of Taranto, and Salento. The latter classification follows the framework established by the "Progetto Tiziano", a comprehensive five-year governmental initiative (2006–2011) aimed at monitoring Apulian aquifers (Bitetto et al. 2008, Fig. 1). Seven sites distributed along the Cervaro River and located in the Sub-Apennine Daunia aquifer were included, as they were reported in the same study investigating sites in the Tavoliere aquifer along the river's course (Cianfanelli et al. 2019). The sites were georeferenced using WGS84 coordinates reported in the original publications, except when these were erroneous or missing. For unpublished observations, the coordinates were provided by the observers. For extended caves, the coordinates indicate the location of the main entrance to the cave system. The cited bibliographic sources correspond to the first known record of a given species sampled at a specific site. When the collection period was not explicitly indicated in the article, the year of publication was used as a proxy. In addition, the dataset specifies whether the observation was repeated in recent years (2020–2024).

Currently, the dataset is available as Suppl. materials of this article accompanied by a summary of the bibliographic sources, recorded species, sampling sites, and metadata. Metadata are also available in the Metadata Catalogue of LifeWatch EIRC (Boulamail et al. 2024, https://doi.org/10.48372/8AM6-VJ47). Data are structured using the Darwin Core standard (Wieczorek et al. 2012) and other controlled vocabularies available in different semantic artefact catalogues (for example, EcoPortal, AgroPortal, and BioPortal). Metadata follows the LifeWatch ERIC Metadata Profile (https://www.lifewatch.eu/download/lifewatch-eric-application-profiles/) of the Ecological Metadata Language (EML 2.2.0). Additionally, the dataset is freely available in the Zenodo (Boulamail 2025a, https://doi.org/10.5281/zenodo.14793315) repositories. In the near future, the STIGE-CLIMAQUIFERI project will archive and publicly share its dataset through the LifeWatch Italy Data Portal, ensuring permanent and interoperable access to the data in accordance with FAIR principles (Findable, Accessible, Interoperable, and Reusable; Wilkinson et al. 2016). The dataset includes detailed information on the chemical and physical parameters recorded at various collection sites (where available from original publications) or current conditions. Observations of further species from ongoing research will be integrated as they become available.

The dataset was organised and analysed within the R free software environment (R Core Team 2024), mostly using the packages sf (Pebesma and Bivand 2023) and OpenStreetMap (Fellows and Stots 2023).

Data description

Dataset

Dataset name: stygofauna_collection_Apulia_1948_2024.csv.
Format name: csv (separators=","; decimal=".").
Character encoding: UTF_8.

Distribution: The dataset is available as a Suppl. materials to this article.
Date of publication: 11/11/2024.
Date of last review: 05/11/2024.
Intellectual rights: This data package is released to the "public domain" under Creative Commons CC0 4.0 "No Rights Reserved".
Language: English.

Management details

Database creators: Sarah Boulamail, Raffaele De Giorgi, Sara Ventruti, Francesco Cozzoli.
Metadata provider: Sara Ventruti, Martina Pulieri.
Temporal coverage: From 1931 to 2024.
Record basis: Literature records and unpublished personal observations.
Sampling design and methods: The data were collected using various methods, including visual surveys, baited traps, and plankton nets. The observations were georeferenced and integrated with previously published data, as well as unpublished records from field experts, primarily in caves and wells across the Apulian region.

Geographic coverage

Study area: Apulia, Italy.
Bounding box: 14.90000 W - 18.60000 E, 42.30000 N - 39.70000 S; WGS84 reference system.
Quality control for geographical data: Quality control was performed by displaying coordinates using the R free software environment (R Core Team 2024) mostly using the packages sf (Pebesma and Bivand 2023) and OpenStreetMap (Fellows and Stots 2023).

Ecological data

Habitat type: Subterranean habitats, primarily caves and wells, spanning karstic environments. Habitat categories include aquatic and terrestrial zones within these subterranean ecosystems.
Quality control for ecological data: Habitat and species-specific ecological information were cross-checked with existing literature and expert knowledge on the biology and ecology of the recorded species.

Literature search

Literature search method: A thorough review of literature on Apulian subterranean fauna was conducted, utilising academic databases and expert observations spanning over a century. Both published and unpublished data were incorporated.

Literature list: A total of 61 publications were referenced and used to gather data about species and the environments they inhabit. The dataset also integrates records from the ongoing PRIN 2022 STIGE-CLIMAQUIFERI project, which has added numerous recent observations, including new data on habitat conditions.

Quality control for literature data: The completeness of the literature was verified by cross-referencing bibliographies and datasets against known records and expert databases.

Taxonomy

Taxonomic ranks: All extant species of Apulian stygofauna and troglofauna were included, spanning multiple genera and families of aquatic and terrestrial organisms.

Species names: The current accepted names for all species have been compiled in the dataset, following standard taxonomic resources and expert validation.

Taxonomic methods: Field-sampled species were identified to the lowest possible taxonomic rank using both classical morphological methods and expert knowledge from biospeleologists.

Taxonomic specialist: Salvatore Inguscio, Joachim Langeneck, Emanuele Mancini

Quality control for taxonomic data: All taxonomic ranks were verified using peer-reviewed literature and expert validation.

Results

Currently, the dataset includes 622 records collected from over 224 sites. It is representative of 109 species, 72 genera, 49 families, and 26 orders of organisms observed in Apulian subterranean environments. Most of the observations were collected from caves (46 sites) and wells (149 sites). Stygobionts represent 30% of the 82 reported aquatic species, while troglobionts represent 60% of the 27 reported terrestrial species. Overall, 29 species were considered endemic to Apulia (Fig. 2).

In terms of contributions to the dataset, the most influential studies are those of Pesce et al. 1978 (206 records) and Karanovic and Pesce 2001 (134 records). A significant contribution (63 records) came from unpublished personal observations collected and validated by Salvatore Inguscio and other amatorial biospeleologists. Additional unpublished and recently collected observations were provided by the ongoing PRIN 2022 project STIGE-CLIMAQUIFERI (27 novel records and multiple recent confirmations of historical records). The reported observations span the entire Apulian region, although they are particularly concentrated in the Salento hydrogeological unit (481 records) due to greater research activity in this area, followed by the Murge Plateau (66 records), Gargano (41 records), Tavoliere (24 records), and Daunia (13 records) units. There are no observations available for Brindisi Plain and Ionian Arch of Taranto (Fig. 3). Most of the records were collected during the seventies and the nineties of the past century and presence data were confirmed by recent investigations (2020–2024) only in a few cases (12% of records).

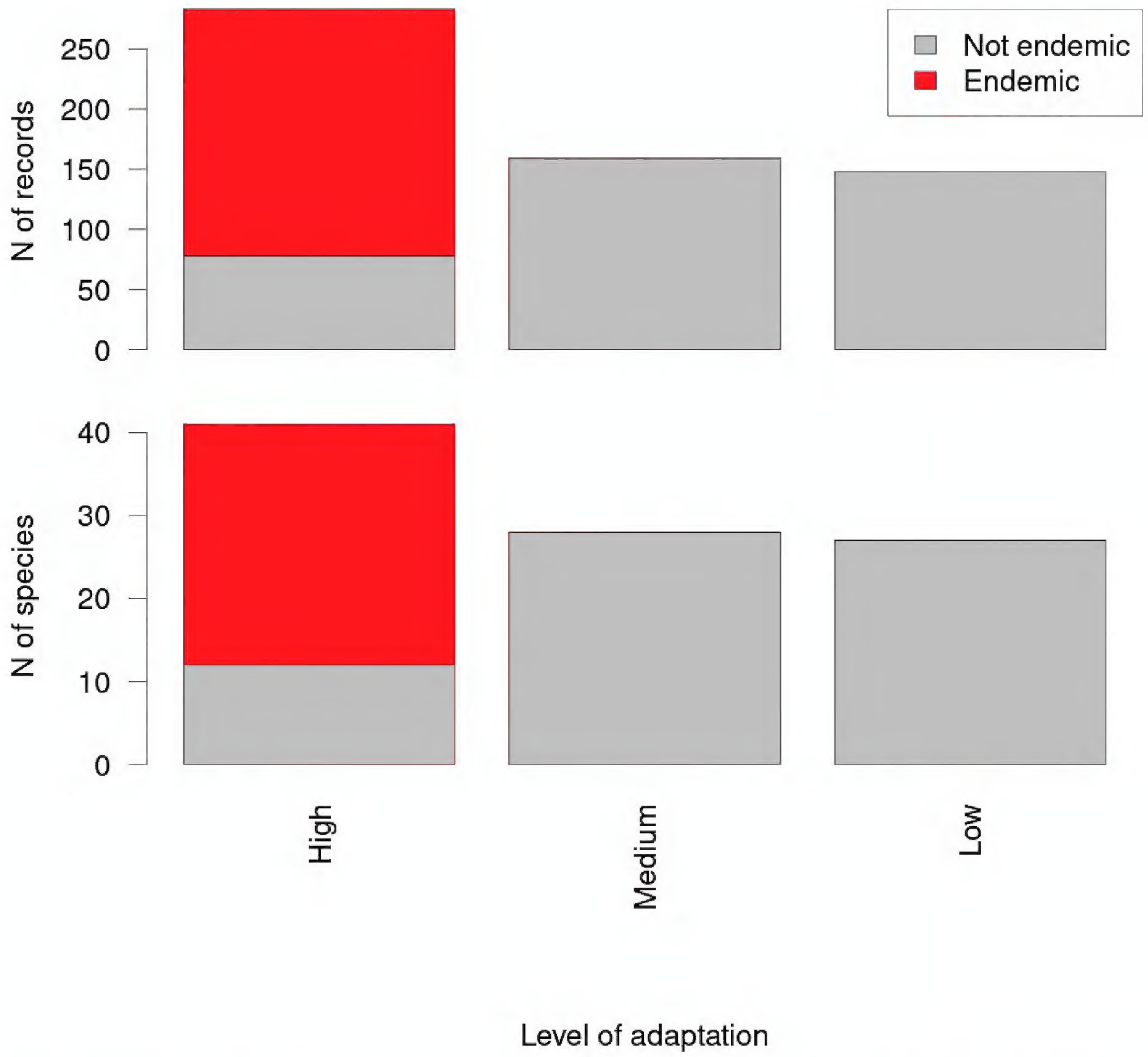

Figure 2. Number of records (top panel) and number of species (bottom panel) according to the level of adaptation to the underground environment (High = stygo/troglobites, Medium = stygo/trogloxenes, and Low = stygo/troglophiles) and the endemic status of the species within Apulia.

The vast majority of the records pertain to Arthropoda, though there are also 41 records of Mollusca, 6 records of Platyhelminthes, 1 record of Annelida, and 1 notable record of Porifera, specifically the stygobitic sponge *Higginsia ciccaresi* Pansini & Pesce, 1998, found in the Zinzulusa caves. The recorded classes of Arthropoda included Copepoda (50 species), Malacostraca (19 species), and Ostracoda (6 species) for aquatic organisms and Arachnida (11 species) for terrestrial organisms (Fig. 4). The most represented families in terms of species richness were Cyclopidae (27 species), Halicyclopidae (6 species), and Ameiridae (6 species). The most common aquatic species were *Spelaeomysis bottazzii* Caroli, 1924 (57 records), *Proasellus banyulensis* (Racovitza, 1919) (57 records), and *Eucyclops* (*Eucyclops*) *serrulatus* (Fischer, 1851) (52 records), while the most common terrestrial species were *Italodytes stammeri* (30 records) and *Hadoblothrus gigas* (13 records). Among the largest European groundwater organisms, the aquatic Decapoda *Typhlocaris salentina* Caroli, 1924 was also relatively common (17 records) (Fig. 5).

The highest number of species (87) was reported in the Salento unit, which exhibited both higher intrinsic biodiversity and more intense investigations. A lower number of species was reported for the Murge Plateau (27), Gargano (23), and Tavoliere

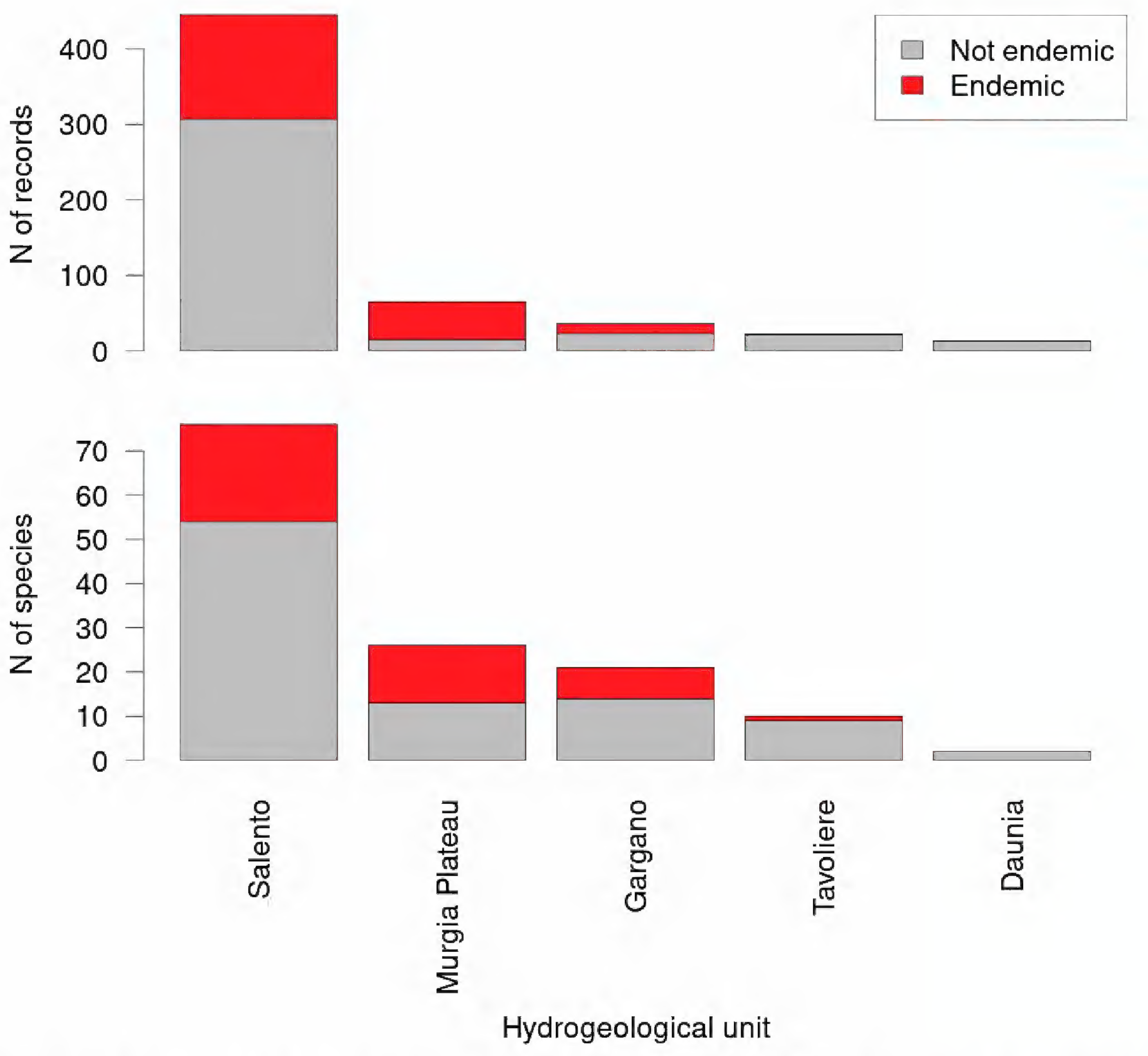

Figure 3. Number of records (top panel) and number of species (bottom panel) according to the Apulian hydrogeological units in which they were observed/collected and the endemic status of the species within Apulia.

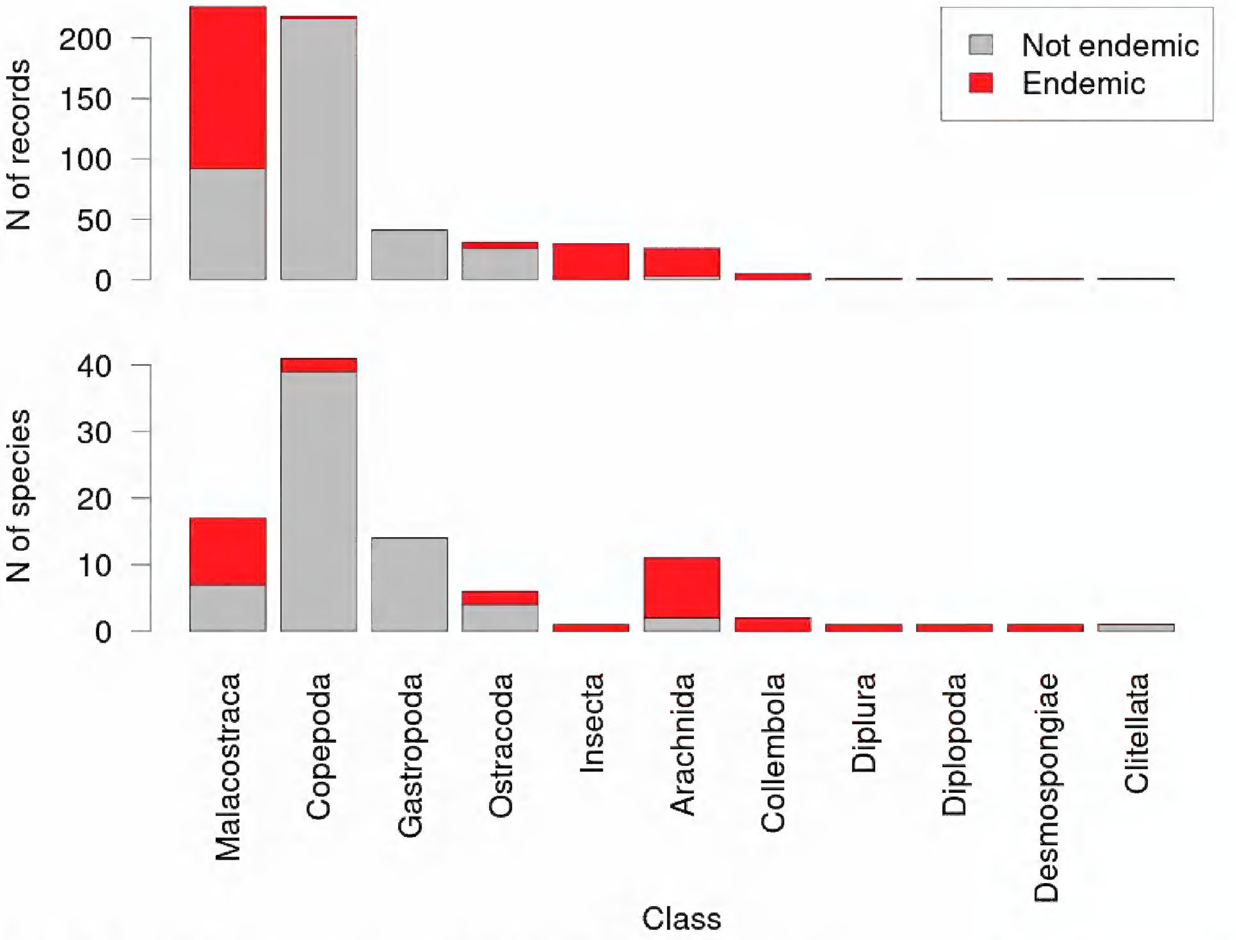

Figure 4. Number of records (top panel) and number of species (bottom panel) for each taxonomic class and the endemic status of the species within Apulia.

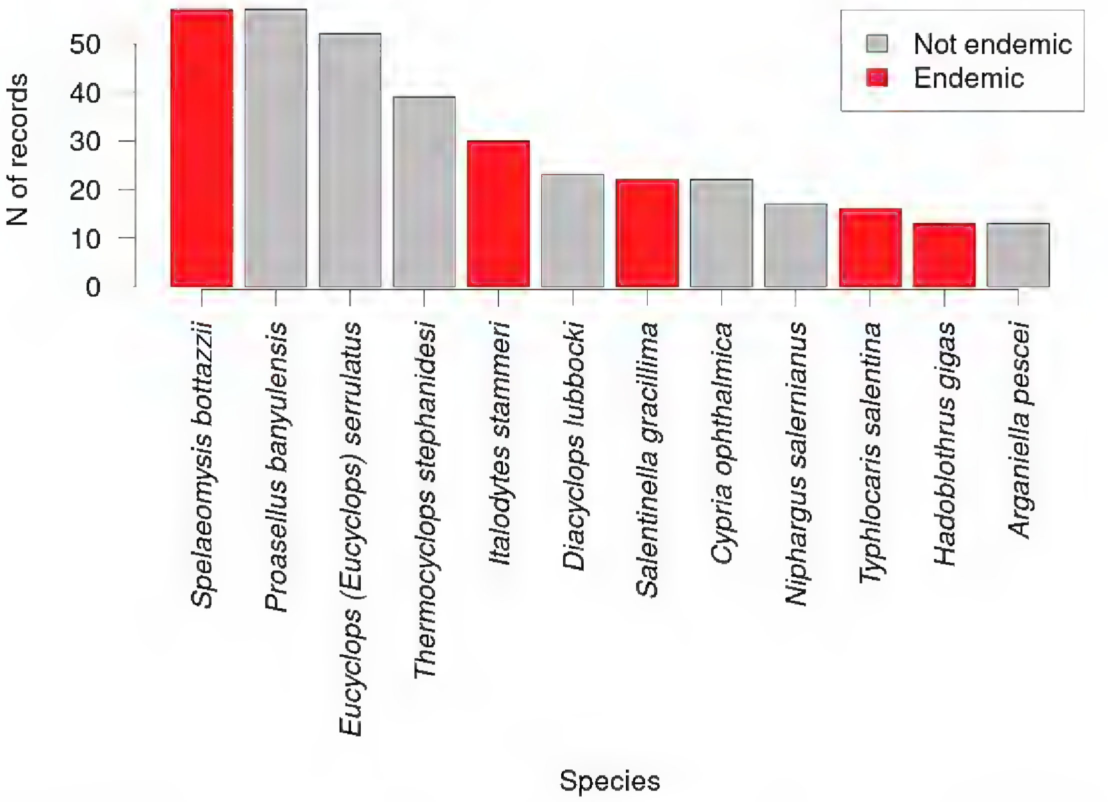

Figure 5. Number of records of the 12 most represented species and endemic status of the species within Apulia.

Figure 6. Species richness of the different sites included in the dataset, for the overall dataset and divided by the three most represented classes (Malacostraca, Copepoda and Gastropoda). "Others" include Arachnida, Clitellata, Collembola, Diplopoda, Diplura, Insecta, Ostracoda, Porifera, and Turbellaria.

(12) units (Fig. 3). The sites of caves Zinzulusa (27 species) and L'Abisso (22 species), along with the drainage tunnel named Fonti di Carlomagno (18 species), all located in Salento, were the sites characterised by the highest number of species (Fig. 6). Castro, where both the caves Zinzulusa and L'Abisso are located, emerges as one of the richest European municipalities in terms of stygofauna biodiversity with a total of 40 reported species occurrences (Fig. 6).

Discussion

By compiling observations from both published research and expert field records, this study fills a significant gap in our knowledge of subterranean biodiversity in Southern Italy. This comprehensive dataset offers a resource for understanding the rich and diverse stygofauna of the Apulian region, particularly its endemic species. However, it also highlights spatial and temporal gaps in knowledge, with some local areas (Tavoliere, Brindisi Plain, Ionian Arch of Taranto) unexplored or strongly underrepresented compared to others (mostly Salento, Gargano, and Murge Plateau). Although the data are not sufficient/appropriate to properly fit a Species Accumulation Curve, the high ratio between sampling effort and the number of observed species suggests that the biodiversity of the less sampled areas could be comparable to that of the more investigated ones. Moreover, many of the observations reported in our dataset were collected decades ago, and only a few of them have been recently repeated. Recent observations have confirmed the presence of notable species, such as *S. bottazzii* and *T. salentina*, at various historical sites. They also highlight the remarkable species richness of the L'Abisso site, although only a portion of the species recorded in the past was collected during recent surveys. However, the limited sampling efforts undertaken do not provide enough data to assess whether there has been a decline in the richness of subterranean species owing to recent environmental changes. While the relative abundance of past observations provides a crucial comparative baseline for interpreting the effects of recent changes, it might not represent the current-day biodiversity condition. Thus, there is a strong need to update these observations through a comprehensive sampling campaign covering the entire territory. Finally, it must be considered that the specimens documented in the literature have not been subjected to reanalysis; therefore, we adhered to the taxonomic classifications provided in the original publications or most recent checklists. Both recent and historical observation have relied on taxonomic identification based on morphological characteristics. Consequently, the presence of cryptic species cannot be ruled out. A reanalysis of these specimens using modern genetic tools could provide deeper insights into the true diversity of the taxa and reveal hidden evolutionary lineages, further enriching our understanding of subterranean biodiversity. The integration of modern data management principles and sharing through platforms such as LifeWatch ITA (https://dataportal.lifewatchitaly.eu/data) ensures that this dataset is accessible,and reusable for future research and conservation plans. As ongoing projects continue to provide new findings, we believe that this updatable database will form the basis for the study and conservation of Apulian stygofauna in the future.

Acknowledgements

We thank Dr. Alberto Potenza, Il Gruppo Speleologico Leccese 'Ndronico, Il Gruppo Speleologico Tricase (GST) and TheMonumentsPeople for their irreplaceable logistical support and sharing of knowledge. We also thank Alessandro Silvestrini,

Michele Bonfrate, Marcello Caramuscio, FORMICA S.R.L., and I.S.T.E. SUD for courtesy and assistance provided during the sampling operations. We extend our gratitude to Dr. Isabella Serena Liso for supporting the spatial analysis, Dr. Simone Cianfanelli for the malacological contribution, Dr. Tiziana Di Lorenzo and Dr. Fabio Stoch for their extremely valuable editorial comments and to Dr. Mattia De Cicco, as well as an anonymous reviewer, for their constructive feedback. Research funded by the project PRIN 2022 STIGE-CLIMAQUIFERI DTA.PN010.014 2022MM8P88_LS8_PRIN2022 - CUP:B53D23012170006 with the support of the project PRIN project "ANCHIALOS" (2022LLNF3N), funded by the Ministry of Universities and Research (Italy) Biodiversa+ (Project DarCo), the European Biodiversity Partnership under the 2021–2022 BiodivProtect joint call for research proposals, co-funded by the European Commission (GA N°101052342) and with the funding organisations Ministry of Universities and Research (Italy), Agencia Estatal de Investigación – Fundación Biodiversidad (Spain), Fundo Regional para a Ciência e Tecnologia (Azores, Portugal), Suomen Akatemia – Ministry of the Environment (Finland), Belgian Science Policy Office (Belgium), Agence Nationale de la Recherche (France), Deutsche Forschungsgemeinschaft e.V. (Germany), Schweizerischer Nationalfonds (Grant N° 31BD30_209583, Switzerland), Fonds zur Förderung der Wissenschaftlichen Forschung (Austria), Ministry of Higher Education, Science and Innovation (Slovenia), and the Executive Agency for Higher Education, Research, Development and Innovation Funding (Romania).

References

Ariani A (1982) Osservazioni e ricerche su *Typhlocaris salentina* (Crustacea, Decapoda) e *Spelaeomysis bottazzii* (Crustacea, Mysidacea). Approccio idrogeologico e biologico sperimentale allo studio del popolamento acquatico ipogeo della Puglia. Annuario dell'Istituto e Museo di Zoologia dell'Universita di Napoli 25: 201–326.

Bitetto F, Polieri V, Barbier V, Balice R (2008) Il sistema di monitoraggio quali-quantitativo dei corpi idrici sotterranei della Puglia: Progetto Tiziano. Atti 12a Conferenza Nazionale ASITA: 473–476.

Bologna MA, Bonato L, Cianferoni F, Minelli A, Oliverio M, Stoch F, Zapparoli M (2022) Towards the new Checklist of the Italian fauna. Biogeographia–The Journal of Integrative Biogeography 37(1): ucl001. https://doi.org/10.21426/B637156271

Boulamail S, De Giorgi R, Ventruti S, Cozzoli F (2024) Gathering knowledge from formal surveys and local experts: A collection of presence-only observations on the (mostly endemic) Apulian Stygofauna and Troglofauna [Data set]. LifeWatch ERIC. https://doi.org/10.48372/8AM6-VJ47

Boulamail S (2025) "Integrating Formal Surveys and Local Knowledge: Insights into the Subterranean Fauna of Apulia", Subterranean Biology. Zenodo. https://doi.org/10.5281/zenodo.14793316

Caroli E (1937) *Stygiomisis hydrutina* n. gen. n. sp., Misidiaceo cavernicolo di Terra d'Otranto, rappresentante di una nuova famiglia. Nota preliminare. Bollettino di Zoologia 8(1): 219–227. https://doi.org/10.1080/11250003709434927

Casarano D, Dragone V, Polemio M (2019) Groundwater resources at salinisation risk: effects of climate and utilisation changes in the case of Apulian coastal aquifers (Southeastern Italy). Acque Sotterranee-Italian Journal of Groundwater 8(1): 53–57. https://doi.org/10.7343/as-2019-374

Cianfanelli S, Talenti E, Nardi G, Bodon M (2019) *Alzoniella cervarensis*: un nuovo idrobiidae freatobio del versante adriatico pugliese (Gastropoda: Caenogastropoda: Hydrobiidae). Bollettino Malacologico 55(1): 23–38.

Cotecchia V, Polemio M (1998) Hydrogeological survey of Apulian groundwater: salinisation, pollution and over-abstraction, 129–136.

Di Lorenzo T, Lunghi E, Aanei C, Altermatt F, Alther R, Amorim IR, Băncilă RI, Bellvert A, Blomberg A, Borges PA, Brad T, and many others (2024) EU needs groundwater ecosystems guidelines. Science 386(6726): 1103–1103. https://doi.org/10.1126/science.ads8140

Fellows I, Stotz JP (2023) OpenStreetMap: Access to Open Street Map Raster Images. R package version 0.4.0. https://CRAN.R-project.org/package=OpenStreetMap

Inguscio S (1992) Osservazioni su una *Typhlocaris salentina* della Zinzulusa. Atti II Conv. Spel. Pugliese, Castellana Grotte, 133–136.

Inguscio S (1998) Misidiacei stigobionti di Puglia. Ideemultimediali.

Inguscio S, Pesce GL, Pagliani T (1999) Nuove località di raccolta di S*tygiomysis hydrutina Typhlocaris salentina* e *Monodella stygicola*. Atti de "*Il Carsismo dell'Area Mediterranea*" suppl. n. 23 Thalassia Salentina 1997: 153–157.

Inguscio S, Rossi E, Parise M, Sammarco M (2010) Grotta Lu Bissu (PU 141), hot spot della biospeleologia italiana. Thalassia Salentina 32: 113–128.

ISPRA [Istituto Superiore per la Protezione e la Ricerca Ambientale] (2014) Memorie descrittive della Carta Geologica d'Italia Vol. 92. [ISBN: 978-88-9311-003-7]

Karaman S (1993) Amphipoda. Fauna d'italia. Ed. Calderini. Bol, 31.

Karanovic I, Pesce GL (2001) Ostracods Crustacea, Ostracoda from underground waters of Puglia southern italy, with redescription of *Pseudolimnocythere hypogea* Klie, 1938. Thalassia Salentina 25: 11–39.

Mammola S, Amorim IR, Bichuette ME, Borges PA, Cheeptham N, Cooper SJ, Culver DC, Deharveng L, Eme D, Ferreira RL, Fišer C (2020) Fundamental research questions in subterranean biology. Biological Reviews 95(6): 1855–1872. https://doi.org/10.1111/brv.12642

Milia A, Torrente MM, Iannace P (2017) Pliocene-Quaternary orogenic systems in Central Mediterranean: The Apulia-Southern Apennines-Tyrrhenian Sea example. Tectonics 36(8): 1614–1632. https://doi.org/10.1002/2017TC004571

Neimanis A (2023) Stygofaunal worlds: Subterranean estrangement and otherwise knowing for multispecies justice. Cultural Politics 19(1): 18–38. https://doi.org/10.1215/17432197-10232445

Parise M (2015) A procedure for evaluating the susceptibility to natural and anthropogenic sinkholes. Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards 9(4): 272–285. https://doi.org/10.1080/17499518.2015.1045002

Pebesma E, Bivand R (2023) Spatial Data Science: With Applications in R. Chapman and Hall/CRC. https://doi.org/10.1201/9780429459016

Pesce GL, Fusacchia G, Maggi D, Tete P (1978) Ricerche faunistiche in acque freatiche del Salento. Thalassia Salentina 8: 3–51.

Pesce GL (1983) Contributo alla conoscenza degli arpacticoidi delle acque sotterranee della regione pugliese. Thalassia Salentina, 13.

Pesce GL (1985) The groundwater fauna of Italy: a synthesis. Stygologia 1(2): 129–159.

R Core Team (2024) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Rossi E, Inguscio S (2001) *Animalia tenebrarum*: *biospeleologia pugliese*. Ideemultimediali.

Ruffo S (1948) Raccolte faunistiche compiute nel Gargano da A. Ghigi e F. P. Pomini, 6. Anfipodi. Acta Pontificiae Academiae Scientiarum 12: 295–310.

Ruffo S (1949) *Monodella stygicola* n. gen. n. sp. nuovo crostaceo Termosbenaceo delle acque sotterranee della penisola Salentina. Archivio Zoologico Italiano 34: 31–48.

Ruffo S (1955) Le attuali conoscenze sulla fauna cavernicola della regione pugliese. Mem. biog. Adr. 3: 1–143.

Stammer HJ (1930) Eine neue Höhlensphaeromidae aus dem Karst, *Monolistra* (*Typhlosphaeroma*) *schottlaenderi*, und die Verbreitung des genus *Monolistra*. Zoologischer Anzeiger 88: 291–304.

Wieczorek J, Bloom D, Guralnick R, Blum S, Döring M, Giovanni R, Robertson T, Vieglais D (2012) Darwin Core: an evolving community-developed biodiversity data standard. PLoS ONE *7*(1): 29715. https://doi.org/10.1371/journal.pone.0029715

Wilkinson MD, Dumontier M, Aalbersberg IJ, Appleton G, Axton M, Baak A, Blomberg N, Boiten JW, da Silva Santos LB, Bourne PE, Bouwman J (2016) The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data 3(1): 1–9. https://doi.org/10.1038/sdata.2016.18

Supplementary material 1

Dataset

Authors: Sarah Boulamail, Sara Ventruti, Raffaele De Giorgi, Francesco Cozzoli

Data type: csv

Link: https://doi.org/10.3897/subtbiol.52.140693.suppl1

Supplementary material 2

Species

Authors: Sarah Boulamail, Sara Ventruti, Raffaele De Giorgi, Francesco Cozzoli

Data type: csv

Link: https://doi.org/10.3897/subtbiol.52.140693.suppl2

Supplementary material 3

Sites

Authors: Sarah Boulamail, Sara Ventruti, Raffaele De Giorgi, Francesco Cozzoli

Data type: csv

Link: https://doi.org/10.3897/subtbiol.52.140693.suppl3

Supplementary material 4

Sources

Authors: Sarah Boulamail, Sara Ventruti, Raffaele De Giorgi, Francesco Cozzoli

Data type: csv

Link: https://doi.org/10.3897/subtbiol.52.140693.suppl4